Studying neutron backgrounds for COHERENT with MARS

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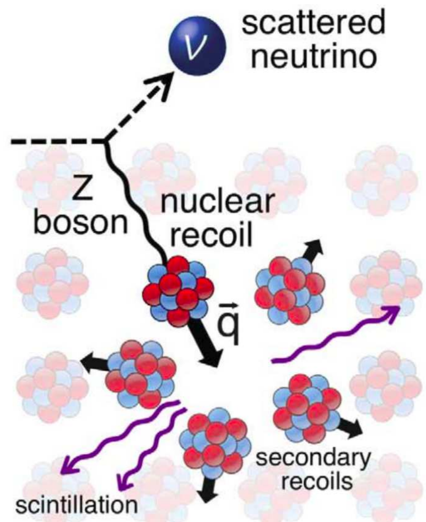
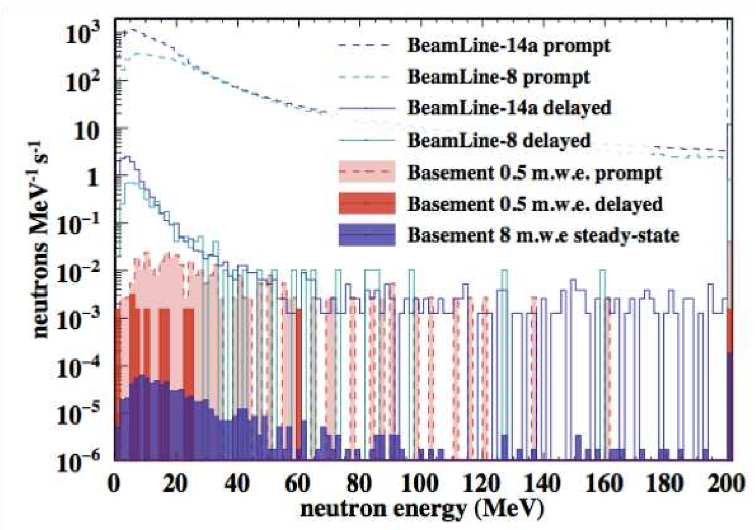
CEvNS and COHERENT

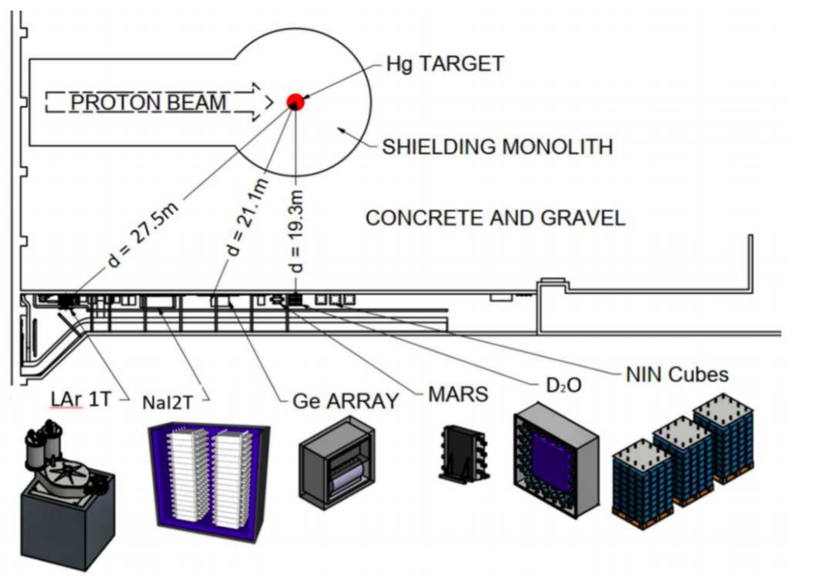
Coherent elastic neutrino-nucleus scattering (CEvNS) is a neutral-current process by which a neutrino causes the full nucleus to recoil. The COHERENT experiment [1] has observed CEvNS using the neutrino production of the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory [2, 3]. As our efforts transition from discovery to precision measurements, we seek a careful understanding of our systematics.



The only CEvNS observable is a low-energy nuclear recoil, so neutrons passing through our sensitive detectors can cause similar signals. Since the SNS is a powerful neutron production facility, we must monitor the flux of beam neutrons which arrive in COHERENT detectors at the same time as the neutrinos. An initial study revealed an area with orders-of-magnitude reduction of this neutron flux. At 8 m.w.e., and shielded from beam neutrons by concrete and gravel, Neutrino Alley was chosen as the deployment location for all COHERENT detectors. This work aims to map the neutron flux near current or planned detector locations.

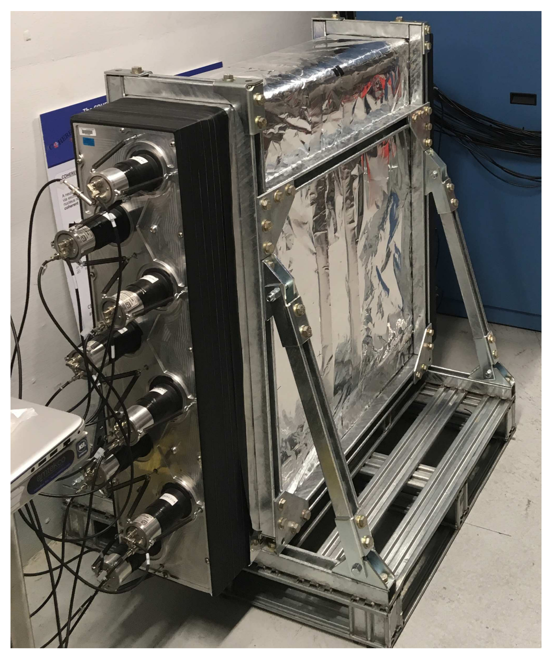


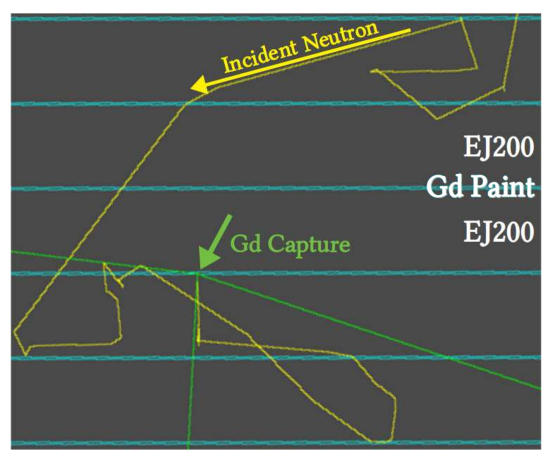
Initial neutron background study



Future of Neutrino Alley

The MARS Detector





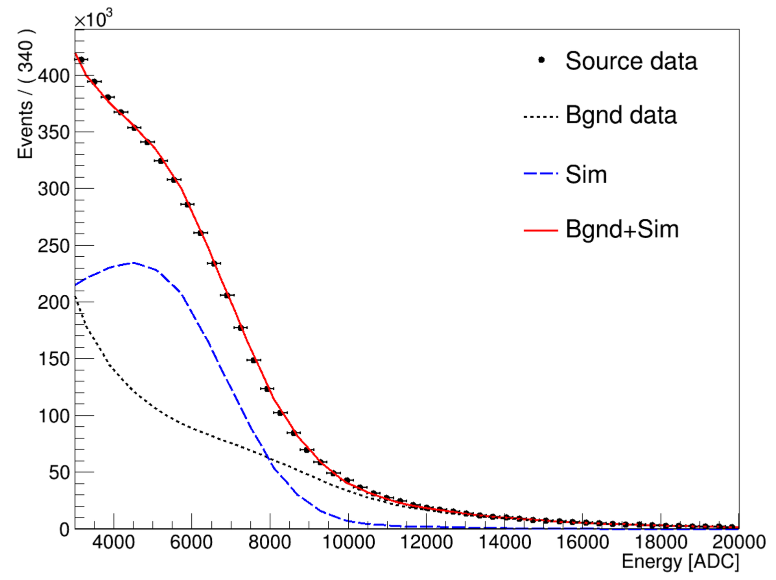
The Multiplicity and Recoil Spectrometer (MARS) is a mobile, gadolinium-doped plastic scintillator develped by Sandia National Laboratories to measure neutron backgrounds for neutrino experiments [4]. This has interleaved layers of EJ200 and Gd-paint-covered Mylar, with 16 PMTs observing a $1\,\mathrm{m} \times 0.75\,\mathrm{m} \times 0.25\,\mathrm{m}$ scintillating volume. The data acquisition is triggered when the light collected by a grouping of four PMTs exceeds threshold. We use an event-pair analysis to identify neutrons, which have the following energy depositions:

- E1: Neutron thermalizes in the scintillator
- E2: Gd de-excites after neutron capture

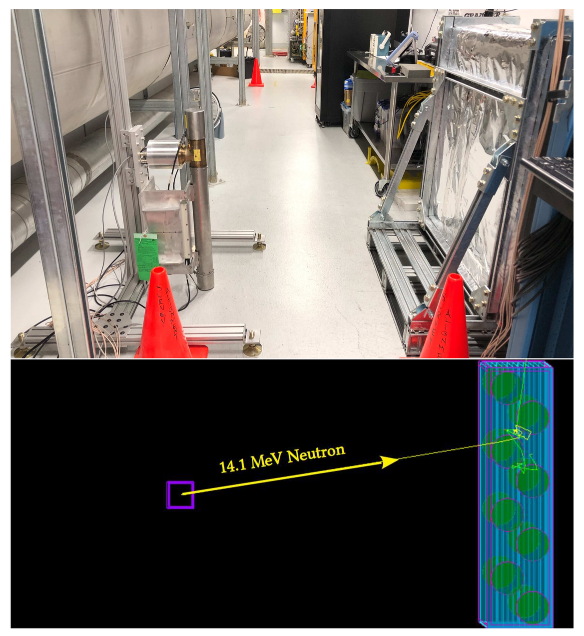
MARS has been deployed to Neutrino Alley since June of 2017, and has collected data in two locations. We are developing a Geant4 simulation of the MARS detector to construct a neutron response matrix that can be used to unfold the energy spectrum of the beam neutrons.

^{60}Co Calibration

We positioned a ^{60}Co source at 20 locations, spaced in a grid with 4 columns and 5 rows across the front face of the MARS detector, to perform a light yield scan. We simulate this gamma source at each scan location, then match the simulation and data to determine the position-dependent light collection and resolution. An example location demonstrating the fit of simulation and background to data is shown to the right.



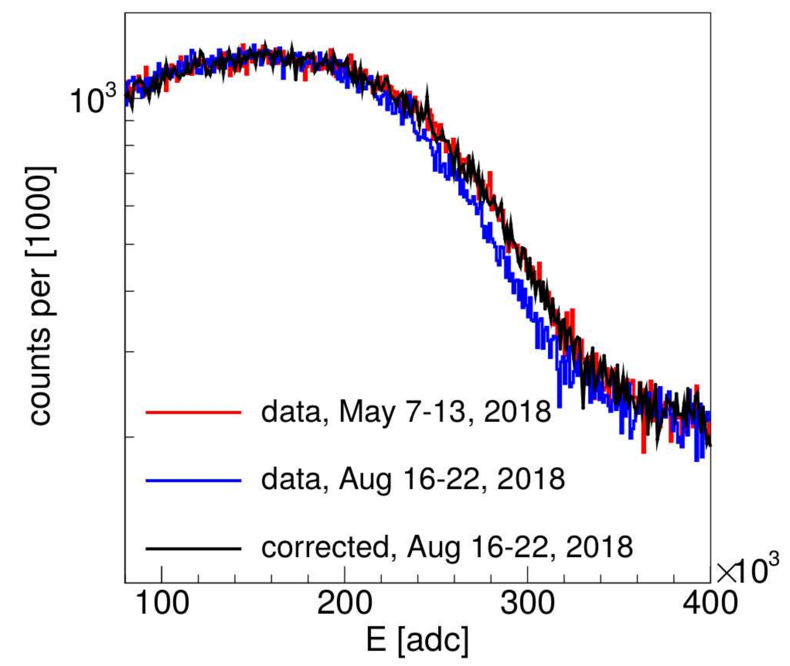
DT Calibration

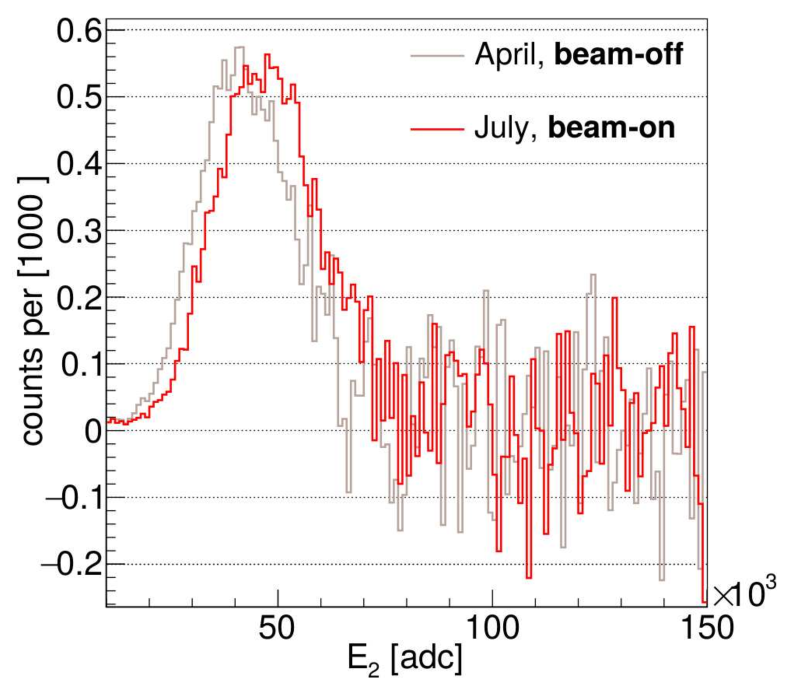


We use a DT generator to study the interactions of 14.1 MeV neutrons within MARS. In particular, we are developing an understanding of the detection and capture efficiencies. A backing detector for the ^{4}He released in the DT fusion provides time-tagging and directionality for the incident neutrons. We will use the measured efficiency from this DT calibration data to tune the energy-dependent efficiency curve derived from the Geant4 simulation.

Using Muons to Monitor MARS Response

We use the cosmic-ray muons that stop (E1) and produce Michel electrons (E2) to monitor the detector response. Since the production rate of Michel electrons is independent of the SNS beam power, we use this spectrum to calibrate the gain over long time periods and apply a linear correction to each day of data. Shown to the right is an example calibration and correction to the energy spectrum using the Michel electron peak.

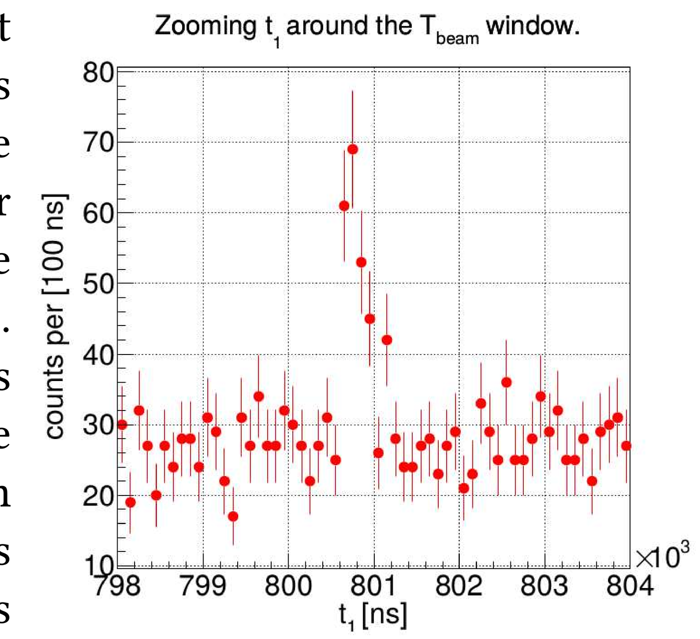


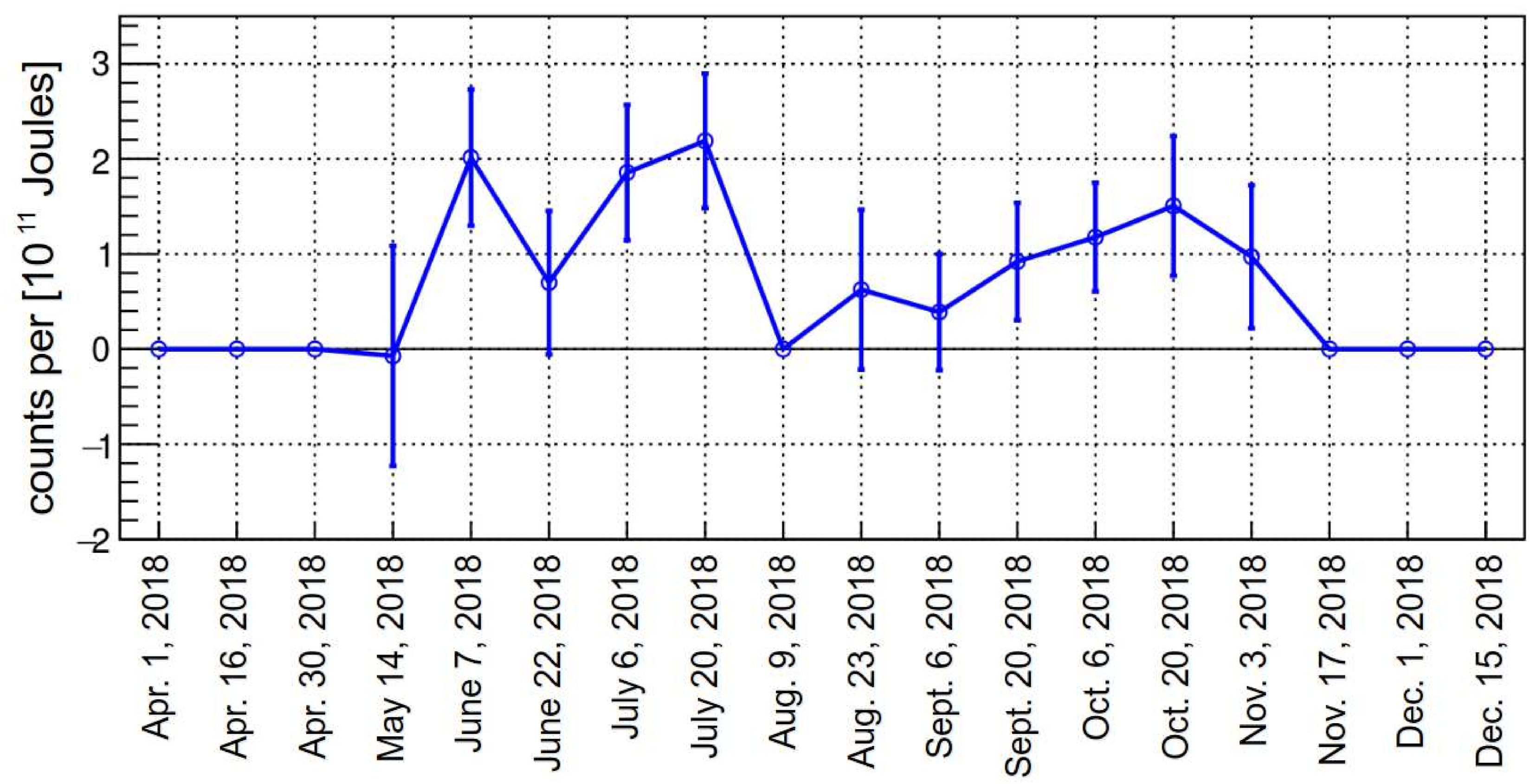


On the other hand, muon interactions with the detector and its surroundings generate a neutron background rate that is independent of the SNS beam status and power. We employ muon-induced neutrons to select energy cuts that account for the spectral shift provoked by the high 511-keV gamma flux emitted by a nearby hot-off-gas pipe. This spectral shift is shown to the left using residual counts for the muon-induced neutrons.

Monitoring Neutrons from the SNS

After adjusting analysis cuts using cosmic-ray muons, we observe an excess in counts coincident with the beam time (right). Using a continuous 2-week period, we count this excess to determine the neutron flux. We normalize by beam power to compare these windows, and can clearly see neutrons associated with the SNS beam (below). The statistical uncertainty is 25% after 3 months of beam-on time. Improved understanding of the efficiency from the DT calibration and neutron response details from the simulation will allow us to measure the spectrum of the prompt neutrons at multiple locations within Neutrino Alley.





Acknowledgements

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References

[1] D. Akimov et al., *COHERENT 2018 at the Spallation Neutron Source*, arXiv:1803.09183, 2018.

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[4] C. Roecker et al., "Design of a transportable high efficiency fast neutron spectrometer", Nucl. Inst. and Meth. A **826**, 21 −30 (2016).